A SIMPLIFIED VERSION OF THE WINGATE ANAEROBIC POWER TEST

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ANAEROBIC POWER TEST*

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SUMMARY

A study was undertaken to develop a modified Wingate anaerobic power (WAP) test that could be administered with a minimum of equipment and personnel. This study was done in the summer of 1989, under contract with the University of North Carolina. The accuracy of using the time to pedal either 240, 270, or 300 M (at a resistance of 0.095 kp/kg of body weight) on a stationary ergometer as a predictor of mean power output from a standard WAP was examined. Forty-four healthy male volunteers participated in the study. Significant correlations were found between completion time and the standard WAP mean power output ($r = -0.55$ to -0.57); however, extensive predictive error (~15%) was found to exist when the bivariate regressions from the correlation analyses were used to estimate mean power output. Multiple regression analysis, however, indicated that use of time to completion, and exercise resistance setting as independent variables resulted in highly significant multiple R values (0.98 to 0.99), and relatively accurate predictive capability (~3% error).

Based upon the statistical results, as well as practical trials completed by this investigator, a protocol employing a pedaling distance of 270 M is recommended. The time to complete this distance at a 0.095 kp/kg of body weight resistance can be used to predict mean power output with the following equations;

$MPO = 458.905 - 1.6839(T) + 9.5277(Re)$; $R = 0.991$; SEE - 16.91

where; MPO = mean power output in Watts

T = time to complete the test in seconds

Re = resistance the subject pedals against in kg

INTRODUCTION

Anaerobic power capacity is considered one of the essential components of physical fitness. This is due to the dependency of many physical activities upon a significant amount of the total energy requirements from anaerobic energy sources (Skinner and McLellan, 1980). The accurate quantification of an individual's anaerobic capacity can serve as an important evaluation criteria for fitness/training assessment (Bouchard, Taylor and Dulac, 1982). Many different testing methods exist for measurement of anaerobic capacity. However, due to physiological concerns and problems in working with a human subject in vivo, current testing methods are at best rough estimates of actual anaerobic power. Presently, the Wingate cycle ergometry test is considered the "gold standard" to which most other tests are compared (Vandewalle, Peres and Monod, 1987). While there are several variations of the Wingate, principally the test consists of a 30 second all-out ride on a ergometer against a set resistance (typically based upon a percentage of a person's body weight). The subject's work output, the product of the resistance, and the distance covered (i.e., pedal revolutions completed), is subsequently converted to their power output (Bouchard, Taylor and Dulac, 1982). For accuracy reasons in the laboratory, the quantification of the power during the Wingate test usually involves a mechanical or electrical monitoring of resistance setting and pedal revolutions. Many times, however, in "field settings" there may be circumstances that will not allow for the administration of the Wingate test under ideal conditions. The intent of this study was to attempt to develop a modified Wingate anaerobic power (WAP) test that could be administered with a minimum of equipment and personnel. Specifically, the accuracy of using the time to complete a fixed pedaling distance on a stationary cycle ergometer as a predictor of actual WAP performance was examined.

METHODS AND PROCEDURES

Forty-four male subjects volunteered for this study. All were healthy and regularly participated in physical training programs; however, none were competitive athletes. A body composition evaluation was performed on each subject by skinfold assessment. The skinfold sites were biceps, triceps, subscapular, and suprailiac. The sum of these values were used to calculate body density using the formula of Durnin and Wormersley (1974). Density values were subsequently converted to percentage body fat with the equation of Brozek et al. (1963). All physical characteristics of the subjects appear in Table 1. Prior to beginning the study, the subjects gave written informed consent to participate.

Each subject completed an initial standard 30 second WAP test (Bar-Or, 1987). Additionally, each subject completed a series of modified WAP tests that consisted of the subject attempting to cover a fixed distance as fast as possible on a cycle ergometer. The distances selected were 240 M (40 revolutions [rev] x 6 M [fly wheel distance]), 270 M (45 rev), and 300 M (50 rev). These distances were selected based upon the results of pilot testing, and after reviewing data from WAP tests previously conducted in our laboratory. During all WAPs (standard and modified), the subjects pedaled against a resistance of 0.095 kp per kg of body weight. Body weight was taken without shoes prior to each WAP trial and recorded to the nearest 0.10 kg. During each of the WAPs, the test administration protocol was as follows; a) the subject took several minutes to stretch, then performed 3 minutes of warm-up on the ergometer at a resistance of 0.5 to 1.0 kp, and during the warm-up ride the subject was asked to perform three 5 second sprints all-out; b) the subject rested (~1 minute), then was asked to start pedaling at progressively faster rates; c) when the subject reached 130 to 150 rpm the resistance setting was engaged; d) the subject was then encouraged to pedal as fast as possible until the completion of the test.

All standard and modified WAP testing was performed on a Monark 868 cycle ergometer. This unit was equipped with a micro-switch, strip-chart recorder apparatus for quantification of pedal revolutions (to the nearest ½ rev). All equipment was calibrated prior to each testing session.

Each subject was asked to perform the standard WAP as well as each of the modified WAPs within a one week period. The order of the testing sessions was ramdomized. Subjects were allowed to complete more than one test per day; however, if they did, adequate rest (several hours) was required to prevent interfering effects (i.e., fatigue). Additionally, six subjects agreed to complete the entire testing sequence a second time; therefore, a total of 50 standard and modified WAP trials were obtained.

Statistically, several analyses were performed. First, mean power outputs were calculated for the 240. 270. and 300 M trials, and compared via t-tests to the measured mean power output from the standard WAP trial.

Similarly, time to completion of the modified trial was compared (t-test) to the time for the standard WAP. Secondly, correlation - regression analyses were performed among the mean power outputs (measured and calculated) and the time to completion results for the three modified WAPs.

RESULTS

Table 2 presents the measured and calculated mean power output (mean $\pm$ SE), as well as the time to completion for each of the trials. The standard WAP results for mean power output (i.e., measured) were found to be in agreement with previously published findings for males of this age (Goslin and Graham), 1985; Kavanagh and Jacobs, 1988). The t-test analysis revealed that the power outputs from all of the modified WAP trials was significantly ($p<0.001$) different from the measured power output. The 240 and 270 M trials were less than the measured (t-ratios = 9.25 and 2.57, df = 48, respectively), while the 300 M trial was greater than the measured (t-ratio = -4.85, df = 48). Similarly, the t-test analysis indicated the time for each of these trials were significantly ($p<0.001$) different from the 30 seconds allowed for the standard WAP. The 240 and 270 M trials took less than 30 seconds to perform (t-ratio = -11.65 and -2.13, df = 48, respectively), while the 300 M trial was longer than 30 seconds in duration (t-ratio = 5.33, df = 48).

The results of the correlation analysis are presented in Table 3. The matrix indicates several highly significant relationships exist among the measures ($r = 0.280$, $p = 0.05$).

Shown in Table 4 are select bivariate and multiple regression equations with the measured mean power output serving as the dependent variable. The independent variables in these equations are time to completion for the respective modified WAP trials, and in the case of the multiple regression equations, the resistance setting used during the WAPs. All of the generated equations were statistically significant ($p<0.001$). The r-squared of the bivariate equations indicated that 31.2% to 32.5% of the total variance of the measured power output could be accounted for by the time variables. However, the r-squared of the multiple equations indicated that the incorporation of the resistance setting as an additional independent variable allowed for a substantially large portion of the total variance in the measured power output to be accounted for (96.8% to 98.2%).

DISCUSSION

The intent of this study was to develop a simplified version of the WAP test that could be used with a minimal amount of equipment and investigative personnel. The results of the study would suggest that a test protocol in which the subject pedals a fixed distance as fast as possible, with the time to completion serving as the measurement criteria, can produce results similar to the standard WAP; provided the resistance setting during the tests are equal. Furthermore, the multiple regression analysis suggests the use of the equations generated can produce an accurate prediction of the mean power output developed during a standard WAP test.

Of the multiple regression equations developed, the 270 M and 300 M equations would seem to have the highest degree of accuracy. This conclusion is based upon the finding that; a) each equation accounted for greater than 98% of the variance in the dependent measure, b) both equations produce relatively small standard error of estimates (2.58% and 2.66%, respectively), and c) each equation was associated with small total errors (2.68% and 2.51%, respectively). Obviously, cross-validation of the equations is necessary in order to more thoroughly evaluate their predictive accuracy. Unfortunately, sufficient subject numbers were not available in this study to allow such a cross-validation to occur.

It is realized that the intent of the study was to produce a protocol that minimized equipment usage, and the testing procedures used here did employ a standard laboratory apparatus for counting revolutions. To assess the applicability of the protocol in more typical field settings, several trials of the 270 M and 300 M tests were performed with modified distance monitoring (i.e., revolution counting) procedures. These procedures involved; a) visual counting of the pedal revolutions by an investigator, b) use of the LCD revolution indicator on a Model 818 Monark ergometer to count revolutions, and c) use of the odometer gauge readings on a Model 868 Monark ergometer to determine distance. Each of these procedures were compared to actual, simultaneous mechanical recordings of the revolutions during the tests. Visual counting of the revolution was found to be an accurate procedure. In 24 trials, only once did a miscount occur, and that was an error of 1 revolution. Likewise, the use of the LCD revolution indicator on the Model 818 Monark was highly accurate; however, due to a lag time in the resetting of the counter to zero, there was a tendency to slightly under count actual revolutions (~1 to 2 rev). This problem could be over come by not resetting the indicator (calculate the difference between the initial and final readings), or by having an assistant reset the indicator immediately prior to engaging the resistance setting. Finally, the use of the gauge odometer on the Model 868 Monark was found to be unacceptable as a means of counting revolutions. This method resulted in an error anywhere from 5 to 10 revolutions per trial.

CONCLUSION AND RECOMMENDATIONS

Statistically, the results indicated little difference exists between the accuracy of using the 45 rev (270 M), or 50 rev (300 M) multiple regression equation for predicting mean power output. Nevertheless, from a practical point of view, the 270 M protocol may be an easier test to administer. During the visual counting of pedal revolutions (distance monitoring), the investigators found the reduced number of revolutions to count (45 versus 50) aided in keeping distance monitoring errors small. Also, from a time perspective, the 270 M WAP test tends to approximate the time of a standard WAP test more closely than the 300 M WAP. In fact, the 300 M WAP test was typically greater than 30 seconds. While the duration extension of the 300 M WAP was only ~3.4 seconds longer than the standard WAP, for the subjects this "extra time" at this high intensity work load is extremely stressful. Therefore, when considering subject safety and discomfort, the 270 M WAP test would appear more advantageous.

REFERENCES

Bar-Or, O. (1987). The wingate anaerobic test. An update on methodology, reliability and validity. Sports Med., 4, 381-394.

Bouchard, C., Taylor, A.W., & Dulac, S. (1982). Testing maximal anaerobic power and capacity. Physiological Testing of the Elite Athlete, Mutual Press Limited, 61-74.

Brozek, J., Grande, F., Anderson, J.T., & Keys, A. (1963). Densiometric analysis of body composition: Revision of some quantitative assumptions. Ann. N. Y. Acad. Sci., 110, 113-140.

Durnin, J.V.G.A., & Wormersley, J. (1974). Body fat assessed from total density and its estimation from skinfold thickness: measurements on 481 men and women aged 16 to 72 years. Br. J. Nutr., 32, 77-97.

Goslin, B.R., & Graham, T.E. (1985). A comparison of 'anaerobic' components of 02 debt and the Wingate test. Canadian Journal of Applied Sports Science, 10, 134-140.

Kavanagh, M.F., & Jacobs, I. (1988). Breath-by-breath oxygen consumption during performance of the Wingate test. Canadian Journal of Applied Sports Science, 13, 91-93.

Skinner, J.S., & McLellan, T.H. (1980). The transition from aerobic to anaerobic metabolism. Research Quarterly for Exercise and Sport, 51, 234-248.

Vandewalle, H., Peres, G., & Monod, H. (1987). Standard anaerobic exercise tests. Sports Med., 4, 268-289.

TABLE 1.
Physical Characteristics of the Subjects
Used in the Study

Measure	Mean	Standard Deviation
Age (y)	22.2	2.1
Height (cm)	176.5	6 [illegible]
Weight (kg)	76.1	10.5
Body Fat (%)	13.5	2.8

TABLE 2.
Results of the Standard and Modified WAPs

Measure	Mean	Standard Error
Mean Power Output (W)		
Measured	649.96	17.40
Predicted		
240 M	556.98	11.71
270 M	623.06	13.38
300 M	697.02	14.69
Time to Completion (sec)		
Standard	30.00	-
240 M	24.49	0.48
270 M	28.84	0.56
300 M	33.35	0.63

TABLE 3.
Correlation Results for Select Measurements

	2	3	4	5	6	7	8
1	.83	.80	.83	-.56	-.55	-.57	.83
2		.98	.99	-.04	-.02	- 03	.99
3			.98	.00	.01	-.02	.98
4				-.04	.02	-.03	.99
5					.99	.93	-.03
6						.97	-.02
7							-.03

1 = measured power output
2 = calculated power output at 240 M
3 = calculated power output at 270 M
4 = calculated power output at 300 M
5 = time to completion of 240 M trial
6 = time to completion of 270 M trial
7 = time to completion of 300 M trial
8 = resistance setting during all trials

TABLE 4.
Results of the Regression Analysis

I. Bivariate

IV	Intercept	Beta	r	SEE	TE
40 rev	-37.128	1.2276	.814	71.79	69.31
45 rev	2.940	1.0331	.783	76.95	75.30
50 rev	-35.550	0.9788	.814	71.84	70.28
40 t	1151.08	-2.0466	-.560	101.85	99.16
45 t	1152.49	-1.7426	-.559	101.95	99.84
50 t	1177.73	-1.5824	-.570	100.96	98.88

II. Multiple

IV	Intercept	Beta	r	SEE	TE
40 t	452.801	-1.9301	.984	21.96	22.15
Res		9.4305			
45 t	458.905	-1.6839	.991	16.81	17.45
Res		9.5277			
50 t	479.057	-1.4955	.990	17.31	16.32
Res		9.4296			

IV = independent variable
rev = revolution (M)
t = time (sec)
TE = total error
Res = resistance (kg)

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of 270 M is recommended. The time to complete this distance at a 0.095 kp/kg of body weight resistance can be used to predict mean power with the following equations;

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where; MPO = mean power output in Watts

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